Internal Communication

Cosmic microwave background dipole, peculiar velocity and Hubble flow

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(Dated: February 1, 2008)

Abstract

Two types of cosmology are discussed and their implications for the observed cmb (cosmic microwave background radiation) dipole are described. Theorems useful for understanding the cause for a cmb dipole are presented. Since the present peculiar velocity of the solar system relative to the GA (Great Attracter) cannot explain the observed cmb dipole, the author presents the possibility of Hubble flow of the GA as a cause in one case and a further peculiar velocity of the GA in the other case.

I. INTRODUCTION

There are two types of cosmology even in the realm of the Friedman universe, one with the center for the expansion of the universe and the other without a center. The Hubble law, $\mathbf{v} = \mathrm{H}_0\ \mathbf{r}$, yields the relationship, $\mathbf{v}_2 - \mathbf{v}_1 = \mathrm{H}_0\ (\mathbf{r}_2 - \mathbf{r}_1)$ for any two galaxies with positions and velocities, $\mathbf{r}_1$, $\mathbf{v}_1$ and $\mathbf{r}_2$, $\mathbf{v}_2$ respectively, where $\mathrm{H}_0 = 100$ h km/s-Mpc is the Hubble constant (with h = 0.5 ˜0.85). For convenience of discussion, we assume the value of H_0 to be 70.0 km/s-Mpc in this article. This equation implies that every point appears to be the center of the expansion. In other words, both types of cosmology yield the same conclusion, as far as the Hubble law is concerned. However, the observed cmb dipole has different implications for the two types of cosmology and observational differences are discussed.

II. TWO TYPES OF COSMOLOGY

In the Friedman universe,

$$ds^2 = dt^2 - a(t)^2(dr^2/(1-kr^2) + r^2 d\theta^2 + r^2 \sin^2(\theta) d\phi^2), \tag{1}$$

with an appropriate source, T^{μ}_{ν} , there are two types of interpretation for the radial coordinate, r.

I) Cosmology A

The origin of the radial coordinate has a physical meaning as a point where the expansion started. Each point of the universe has a Hubble flow velocity relative to the origin that is proportional to the distance from the origin. As is discussed in the introduction, the linearity of the Hubble law makes every point in the universe look like a center for the expansion of the universe.

II) Cosmology B

The universe resides on the surface of an expanding balloon. The center does not exist in the universe. (It exists outside the universe.) The origin of the coordinate can be chosen at any point but there is no special significance for such a choice. The Hubble law is naturally built into the framework. There is no velocity associated with each point of the universe, but the relative distance and relative velocity of any two points increase with the expansion

of the balloon. Each point is equivalent relative to a distant cmb emittor and there is no cmb dipole at any point except that due to a peculiar velocity in a cluster.

I will discuss the implication of the observed cmb dipole in cosmologies A and B.

III. THE CMB DIPOLE IN THE TEMPERATURE DISTRIBUTION IN COSMOLOGY A

A dipole component was observed in the temperature distribution in the cmb measurement. The cmb dipole for blueshift for the solar system [1] is given by

$$v = 371 \pm 0.5\ km/s, \qquad l = 264.4 \pm 0.3^\circ, \qquad b = 48.4 \pm 0.5^\circ. \tag{2}$$

Or equivalently, the cmb dipole for redshift is

$$v = 371 \pm 0.5\ km/s, \qquad l = 84.4 \pm 0.3^\circ, \qquad b = -48.4 \pm 0.5^\circ. \tag{3}$$

By using the observation of a peculiar velocity for the solar system[2],[3], one can compute the cmb dipole component of the cluster (Virgo) center and that of the supercluster (GA) center. The detailed calculation of the cmb dipoles at the cluster centers will be performed below, and it will be shown that the cmb dipoles at the cluster centers are much larger than that of the solar system. If the cmb dipole at the cluster center were zero, one could conclude that the observed cmb dipole would be due to the peculiar velocity. In other words, the observed cmb dipole cannot be explained in terms of the peculiar velocity. In order to understand the meaning of the observed cmb dipole, the author presents pertinent theorems.

Theorem 1 *With the assumption of the existence of a center for expansion of the universe, Hubble flow creates a cmb dipole with redshift in the direction of the Hubble flow with the magnitude of the Hubble flow velocity.*

Proof. Let the velocities of the Hubble flow and the cmb emitter in the direction of the Hubble flow be v_H and v, respectively. Relating an equivalent velocity of the cmb emittor v to the expansion rate $1 + z$ by

$$\sqrt{\frac{1 + v/c}{1 - v/c}} = 1 + z, \tag{4}$$

one gets

$$v/c = \frac{(1+z)^2 - 1}{(1+z)^2 + 1} = 1 - 2\frac{1}{(1+z)^2} = 1 - 2x10^{-6} \tag{5}$$

for $z = 1000$. The relative velocity is $v_+ = (v - v_H)/(1 - vv_H/c^2)$. The analogous velocities in the opposite direction are $-v_H$ and $v - 2v_H$, and the relative velocity is $v_- = (v - 2v_H + v_H)/(1 + (v - 2v_H)v_H/c^2)$ in the opposite direction. These relative velocities are then expressed for $v \approx c$ and $v_H \ll c$

$$v_+ \approx v - v_H + v_H \tag{6}$$

and

$$v_- \approx v - v_H - v_H. \tag{7}$$

This proves the statement. Obviously, the cmb dipole vanishes at the center of the universe. ■

Theorem 2 *The cmb dipoles for redshift at the center of a cluster and at a member galaxy with a peculiar velocity* $\mathbf{v}_p$ *are related by*

$$\mathbf{v}(\textit{dipole at the clustercenter}) = \mathbf{v}(\textit{dipole at the galaxy}) - \mathbf{v}_p + \mathbf{v}(\textit{clustercenter} - \textit{galaxy}) \tag{8}$$

where

$$\mathbf{v}(A - B) = \mathbf{v}(A) - \mathbf{v}(B) \tag{9}$$

Proof. The peculiar velocity plays a role similar to Hubble flow, as far as the cmb dipole is concerned. This can be seen by considering the case where the peculiar velocity $\mathbf{v}_p$ and Hubble flow $\mathbf{v}_H$ are parallel. In this case, the galaxy is at rest with respect to a galaxy with Hubble flow, $\mathbf{v}_H + \mathbf{v}_p$. Since both galaxies should have the same cmb dipole, the above statement is established. The term, $\mathbf{v}(A) - \mathbf{v}(B) = H_0(\mathbf{r}_A - \mathbf{r}_B)$, is for adjustment of the Hubble law. In fact, the necessity of the term, $\mathbf{v}(\textit{center} - \textit{galaxy}) = \mathbf{v}(\textit{center}) - \mathbf{v}(\textit{galaxy})$, is understood when the formula is applied to galaxies at the clustercenter and a galaxy in the limit of vanishing peculiar velocity. ■

Lemma *The center of the universe is characterized as a point of the universe where the cmb dipole has an intrinsically vanishing value.*

The term intrinsically vanishing value is used, since an accidentally vanishing value for a cmb dipole can occur for a point galaxy in a cluster for which the Hubble flow of the cluster and the peculiar velocity of the galaxy have identical magnitude and opposite direction.

Clearly, that galaxy is at rest relative to the center of the universe at that instant. Hereafter a cmb dipole implies a redshift dipole unless otherwise stated.

The peculiar velocity of the sun relative to the Virgo center of the local cluster is estimated to be [2]

$$v = 415 \ km/s, \quad l = 335^\circ, \quad b = 7^\circ \tag{10}$$

or

$$v = 630 \ km/, \quad l = 330^\circ, \quad b = 45^\circ \tag{11}$$

We examine these two possibilities. The outcomes are listed in this order for each case. Using Theorem 2, one computes the cmb dipole at the Virgo center, which is located at

$$v = 1050 \pm 200 \ km/s, \quad l = 287^\circ, \quad b = 72.3^\circ \tag{12}$$

corresponding to a distance of 15 ± 3 Mpc. The key formula is

$$\mathbf{v}(dipole\ at\ Virgo) = \mathbf{v}(dipole\ at\ the\ Sun) - \mathbf{v}_p(Sun/Virgo) + \mathbf{v}(Virgo) \tag{13}$$

For the cmb dipole at the Virgo center, one obtains

$$v = 728.3 \pm 148 \ km/s, \quad l = 336.0 \pm 8.2^\circ, \quad b = 67.4 \pm 11.3^\circ \tag{14}$$

$$v = 418.8 \pm 47 km/s, \quad l = 328.8 \pm 6.4^\circ, \quad b = 41.5 \pm 28.0^\circ \tag{15}$$

depending on the two choices of peculiar velocity. We note that the Cartesian coordinates for (v, l, b) are expressed as $(v \cos b \cos l, v \cos b \sin l, v \sin b)$.

Further, the Virgo cluster is considered to be part of a supercluster centered around the GA. In order to compute the cmb dipole at the GA, one assumes the position of the GA to be [3]

$$v = 4200 \ km/s, \quad l = 309^\circ, \quad b = 18^\circ \tag{16}$$

or

$$v = 3000 \ km/s, \quad l = 305^\circ, \quad b = 18^\circ \tag{17}$$

and the infall velocity of the Virgo center to the GA to be

$$v_{in} = 1000 \pm 200 km/s \tag{18}$$

The direction of the infall is determined by

$$\mathbf{v}(GA - V) = \mathbf{v}(GA) - \mathbf{v}(Virgo) \tag{19}$$

resulting in

$$v(GA-V) = 3712.3 \pm 75\ km/s, \quad l(GA-V) = 310.9 \pm 0.4^\circ, \quad b(GA-V) = 4.6 \pm 2.8^\circ \tag{20}$$

for Eq.(16) and

$$v(GA-V) = 2552.5 \pm 59\ km/s, \quad l(GA-V) = 307.2 \pm 1.6^\circ, \quad b(GA-V) = 1.6 \pm 3.0^\circ \tag{21}$$

for Eq. (17).

Using Theorem 2, one can compute the cmb dipole at the GA by

$$\mathbf{v}(dipole\ at\ GA) = \mathbf{v}(dipole\ at\ Vigo) - \mathbf{v}(Virgo\ infall) + \mathbf{v}(GA-V), \tag{22}$$

where the direction of the infall is given by Eq. (20) or Eq. (21). Then, the cmb dipole at the GA is given by

$$v = 2609.3 \pm 120\ km/s, \quad l = 308.1 \pm 0.2^\circ, \quad b = 19.9 \pm 3.4^\circ \tag{23}$$

$$v = 2459.1 \pm 98\ km/s, \quad l = 308.6 \pm 0.6^\circ, \quad b = 11.6 \pm 3.9^\circ \tag{24}$$

for Eq. (16), and

$$v = 1455.6 \pm 142\ km/s, \quad l = 301.3 \pm 0.6^\circ, \quad b = 25.5 \pm 5.3^\circ \tag{25}$$

$$v = 1286.6 \pm 104\ km/s, \quad l = 302.0 \pm 0.7^\circ, \quad b = 10.4 \pm 7.3^\circ \tag{26}$$

for Eq. (17).

Based on Theorem 1, one may assume that the cmb dipole at the GA calculated above is due to the Hubble flow of the center of the GA supercluster. Then, one can compute the position of the center for expansion of the universe by

$$\mathbf{v}(universe\ center) = \mathbf{v}(GA\ center) - \mathbf{v}(cmb\ dipole\ at\ GA) \tag{27}$$

The position of the universe center thus obtained is

$$v_c = 1595.3 \pm 196\ km/s, \quad l_c = 310.5 \pm 0.1^\circ, \quad b_c = 14.8 \pm 1.5^\circ \tag{28}$$

$$v_c = 1779.6 \pm 184\ km/s, \quad l_c = 309.7 \pm 0.2^\circ, \quad b_c = 26.8 \pm 2.7^\circ \tag{29}$$

for Eq. (16), and

$$v_c = 1585.4 \pm 196\ km/s, \quad l_c = 308.1 \pm 0.2^\circ, \quad b_c = 13.0 \pm 1.6^\circ \tag{30}$$

$$v_c = 1759.3 \pm 181\ km/s, \quad l_c = 307.4 \pm 0.0^\circ, \quad b_c = 25.3 \pm 2.9^\circ \tag{31}$$

for Eq. (17). Conversion to the ordinary distance scale yields 22.8 ± 2.8 *Mpc*, 25.4 ± 2.6 *Mpc* for Eq. (16) and 22.6 ± 2.8 *Mpc*, 25.1 ± 2.6 *Mpc* for Eq. (17).

The last set of expressions for the universe center can be obtained alternatively directly from the total peculiar velocity of the solar system towards the GA supercluster center and the cmb dipole of the sun. Using Eq. (13), Eq. (22) and Eq. (27), one gets

$$\mathbf{v}(universe\ center) = -(\mathbf{v}(dipole\ at\ the\ Sun) - \mathbf{v}_p(total)) \tag{32}$$

where

$$\mathbf{v}_p(total) = \mathbf{v}_p(Sun/Virgo) + \mathbf{v}_p(Virgo/GA) \tag{33}$$

is the total peculiar velocity of the sun towards the GA. From Eq. (10), Eq. (11), Eq. (18), Eq. (20) and Eq. (21), one finds the total peculiar velocity to be

$$v = 1389.2 \pm 198\ km/s, \quad l = 317.9 \pm 1.2^\circ, \quad b = 5.4 \pm\ 0.1^\circ \tag{34}$$

$$v = 1519.1 \pm 190\ km/s, \quad l = 316.8 \pm 0.9^\circ, \quad b = 20.2 \pm 2.4^\circ \tag{35}$$

for Eq. (16), and

$$v = 1379.7 \pm 189\ km/s, \quad l = 315.2 \pm 1.4^\circ, \quad b = 3.3 \pm\ 0.2^\circ \tag{36}$$

$$v = 1497.6 \pm 189 km/s, \quad l = 314.2 \pm 1.1^\circ, \quad b = 18.4 \pm\ 2.5^\circ \tag{37}$$

for Eq. (17). Application of Eq. (32) yields the same result for the coordinates of the center of the universe obtained above.

In the end, the author has arrived at the following conclusion.

Theorem 3 *The Hubble flow of the solar system is nothing but*

$$\mathbf{v}_H(the\ Sun) = \mathbf{v}(the\ cmb\ dipole\ at\ the\ Sun) - \mathbf{v}_p(the\ total\ peculiar\ velocity\ of\ the\ Sun). \tag{38}$$

IV. THE CASE FOR COSMOLOGY B

In this case, there is no cmb dipole at any point except due to a peculiar velocity in a cluster. Therefore

$$\mathbf{v}(dipole\ at\ the\ Sun) - \mathbf{v}_p(total) - \mathbf{v}_p(GA/X) = 0 \tag{39}$$

or equivalently

$$\mathbf{v}_p(GA/X) = \mathbf{v}(dipole\ at\ the\ Sun) - \mathbf{v}_p(total) \tag{40}$$

must be a peculiar velocity of the GA supercluster towards an unknown center X. Comparing Eq (32) and Eq (40) or Eq (38), it is obvious

$$\mathbf{v}_p(GA/X) = -\mathbf{v}(universe\ center) = \mathbf{v}_H(the\ Sun). \tag{41}$$

In other words, -(the center coordinate) or the Hubble flow of the sun in cosmology A plays the same role as the extra peculiar velocity of the GA towards unknown object X.

V. SUMMARY AND DISCUSSION

The observed cmb dipole cannot be explained by the present status of the peculiar velocity of the solar system, neither relative to the center of the Virgo cluster, nor relative to the center of the GA supercluster. Instead, it implies a large cmb dipole at the location of the GA. As far as I know, up to now there has been no explanation for such a cmb dipole at a supercluster center. Using Theorem 1, the author has presented an explanation for a cmb dipole at the GA in terms of Hubble flow. In other words, the author presented an explanation for the observed cmb dipole as a result of the Hubble flow of the GA and the peculiar velocity of the solar system towards the GA. This interpretation inevitably determines the location of the center for the expansion of the universe in cosmology A. Alternatively, in cosmology B the GA cluster center must have a peculiar velocity towards X in the southern hemisphere. It is important to determine whether a peculiar velocity for the GA center with the value given by Eq. (40) can be found by future observation. If not, cosmology A prevails.

Acknowledgments

The author would like to thank the members of the Physics Department and the Astronomy Department of the University of Michigan for useful information.

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